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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau(43) International Publication Date  
7 August 2003 (07.08.2003)

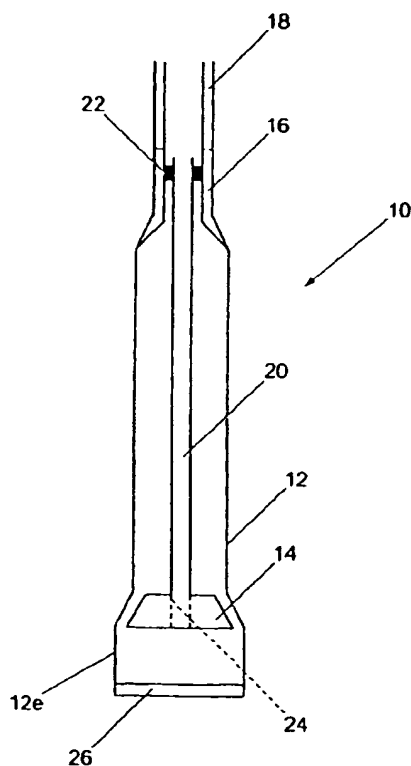
PCT

(10) International Publication Number  
WO 03/064813 A1

- (51) International Patent Classification<sup>7</sup>: **E21B 43/10** (74) Agent: **MURGITROYD & COMPANY**; 165-169 Scotland Street, Glasgow G5 8PL (GB).
- (21) International Application Number: **PCT/GB03/00138**
- (22) International Filing Date: 16 January 2003 (16.01.2003) (81) Designated States (*national*): AE, AG, AI, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MY, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
0201955.2 29 January 2002 (29.01.2002) GB
- (71) Applicant (*for all designated States except US*): **e2TECH LIMITED** [GB/NL]; Shell International B.V., PO Box 384, NL-2051 CJ The Hague (NL).
- (72) Inventor; and
- (75) Inventor/Applicant (*for US only*): **BURGE, Philip, Michael** [GB/GB]; Blackchambers, Westhill, Aberdeenshire AB32 7BU (GB).
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR EXPANDING TUBULAR MEMBERS



(57) Abstract: Apparatus and methods of expanding tubular members are disclosed. In one embodiment, the apparatus includes a vibrating device (16) that is capable of imparting a longitudinal and/or lateral and/or oblique vibration to a tubular member (12) or string (18) as it is being run into a borehole or wellbore. In another embodiment, the vibrating device (16) imparts a longitudinal and/or lateral and/or oblique vibration to a tubular member (12) and/or expander device (14), as the tubular member (12) is being radially expanded by the expander device (14).



WO 03/064813 A1

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**Published:**

--- with international search report  
before the expiration of the time limit for amending the  
claims and to be republished in the event of receipt of  
amendments

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

1     "Apparatus and Method for Expanding Tubular Members"

2

3     The present invention relates to apparatus and  
4     methods for expanding tubular members, and in  
5     particular apparatus and methods that help to avoid  
6     downhole tubulars from becoming differentially stuck  
7     when running the tubulars into a borehole and/or when  
8     radially expanding them.

9

10    It is known to use downhole tubular members that are  
11    capable of being radially expanded to case, line and  
12    repair boreholes. The tubular members are typically  
13    of a ductile material so that they can undergo  
14    plastic and/or elastic deformation to increase their  
15    inner and outer diameters.

16

17    Differential sticking is a common occurrence in oil,  
18    gas and water wells and is the name given to the  
19    jamming of a tubular member in the borehole that is  
20    usually caused by a high differential pressure  
21    between the borehole and the surrounding formation.  
22    The pressure in the borehole can be significantly

---

1 higher than the pressure in the formation, and the  
2 higher pressure in the borehole tends to push  
3 downhole tubulars and other apparatus towards the  
4 wall of the borehole where they can become jammed or  
5 stuck.

6  
7 This differential sticking can be made worse by a  
8 build up of solids or "filter cake" (filtrate) on the  
9 face of the borehole. The build up is typically due  
10 to fluid (e.g. mud) loss into the formation because  
11 the differential pressure between the borehole and  
12 the formation causes the fluid to be forced from the  
13 high pressure borehole into the low pressure  
14 formation. Solid particles in the mud separate out  
15 as the larger particles cannot pass into the  
16 formation because of the structure thereof, and the  
17 particles tend to form a build up of solids or  
18 filtrate on the wall of a borehole. The filtrate is  
19 typically a relatively thin coating and can help to  
20 seal and stabilise the borehole walls, but too much  
21 of this can cause the downhole tubulars and apparatus  
22 to stick to the walls, particularly when the tubulars  
23 stop moving, and the filtrate acts as a seal.

24  
25 According to a first aspect of the present invention,  
26 there is provided apparatus for expanding a tubular  
27 member, the apparatus comprising a vibrating device  
28 and an expander device.

29

30 According to a second aspect of the present  
31 invention, there is provided a method of expanding a

1 tubular member in a borehole, the method comprising  
2 the step of vibrating the tubular member before,  
3 during and/or after expansion.

4

5 The present invention also provides a method of  
6 preventing a string from becoming stuck in a  
7 wellbore, the method comprising the steps of  
8 vibrating the string while being run into the  
9 wellbore.

10

11 The string may comprise a string of tubular members,  
12 downhole apparatus (e.g. tools, instrumentation,  
13 drill bits etc), or a combination of these and other  
14 components.

15

16 The vibrating device is typically capable of  
17 imparting a longitudinal and/or lateral vibration to  
18 the expander device and/or the tubular member. It  
19 will be appreciated that a longitudinal vibration  
20 means a vibration that is applied on a longitudinal  
21 axis of the tubular member and/or the expander  
22 device, or on an axis that is coplanar or parallel to  
23 the longitudinal axis of the tubular member and/or  
24 expander device. A lateral vibration is typically a  
25 vibration on an axis that extends across the  
26 longitudinal axis of the tubular member (e.g. one  
27 that is substantially perpendicular to the  
28 longitudinal axis of the tubular member and/or the  
29 expander device), or on an axis that is coplanar or  
30 parallel to the axis that is substantially  
31 perpendicular to the longitudinal axis of the tubular

1 member and/or expander device. It will also be  
2 appreciated that the vibrations may be on an oblique  
3 axis that is, for example, across the longitudinal  
4 axis but not perpendicular thereto. The vibrating  
5 device is preferably capable of applying at least  
6 longitudinal vibration to the tubular member. The  
7 vibrating device may comprise a Baker Oil Tools  
8 RATTLER™ downhole tool or the like. The vibrating  
9 device provides the advantage that the tubular member  
10 and/or the expander device can be vibrated on a  
11 longitudinal and/or lateral and/or oblique axis  
12 whilst being run into the borehole. Thus, the  
13 tubular member is less likely to become stuck due to  
14 differential pressure. Also, the vibrating device  
15 provides the advantage that the tubular member and/or  
16 the expander device can be vibrated on a longitudinal  
17 and/or lateral and/or oblique axis whilst the member  
18 is being radially expanded. This reduces the amount  
19 of friction between the expander device and the  
20 tubular member, making the expansion process more  
21 efficient and reduces the possibility of the expander  
22 device becoming stuck.

23  
24 The vibrations are typically applied at least for the  
25 duration of the expansion process and/or whilst the  
26 tubular member or string is being run into the  
27 borehole.

28  
29 Optionally, the vibrations may be applied after  
30 completion of the expansion process. For example,  
31 vibrations may be applied whilst the apparatus is

---

1 being retrieved from the borehole to reduce friction,  
2 or during circulation of cement.

3  
4 The vibrating device is typically actuated by the  
5 flow of fluid (e.g. mud, water, brine, cement etc)  
6 therethrough. Other means of actuation may also be  
7 used depending upon the particular type of vibrating  
8 device. For example, the vibrating device may be  
9 electrically-operated or petrol- or diesel-driven.

10  
11 The expander device typically comprises an expansion  
12 cone. The cone is preferably of a material that is  
13 harder than the tubular member that it has to expand.  
14 Steel or a steel alloy is typically used. Tungsten  
15 carbide or a ceramic material may also be used.  
16 Combinations of these and/or other materials may also  
17 be used. For example, a harder material (e.g.  
18 ceramic, tungsten carbide etc) may be used to coat  
19 the portion(s) of the cone that come into contact  
20 with the tubular member during expansion thereof.

21  
22 The expander device is typically attached to a  
23 conduit, such as a portion of drill string, a coiled  
24 tubing string or the like. It is preferable that the  
25 expander device be coupled to a conduit having a  
26 relatively small diameter. The vibrating device is  
27 preferably coupled (e.g. by screw threads) to the  
28 tubular member that is to be expanded. The tubular  
29 member is typically coupled to a string (e.g. a  
30 string of drill pipe or a coiled tubing string). In  
31 this particular embodiment, a seal assembly is

---

1 preferably located between the conduit and the  
2 tubular member. The seal assembly preferably allows  
3 the conduit with the expander device to move, whilst  
4 the tubular member and string remain stationary.  
5 This has the advantage that the expansion of the  
6 tubular member does not require movement of the  
7 string.

8  
9 Alternatively, the vibrating device may be coupled  
10 into the same conduit as the expander device. The  
11 tubular member is typically coupled to a string (e.g.  
12 a string of drill pipe or a coiled tubing string).  
13 In this particular embodiment, a seal assembly is  
14 preferably located between the conduit and the  
15 string. The seal assembly preferably allows the  
16 conduit with the expander device to move, whilst the  
17 tubular member and string remains stationary. This  
18 has the advantage that the expansion of the tubular  
19 member does not require movement of the string.

20  
21 The expander device is preferably provided with a  
22 through-bore or aperture that allows fluid to pass  
23 through the conduit to which it is attached, and also  
24 through the expander device.

25  
26 An end of the tubular member is preferably closed.  
27 The end can be closed using a threaded cap, ball  
28 catcher or the like. Thus, fluid pressure is  
29 retained within the tubular member. The end of the  
30 tubular member is optionally pre-expanded so that the  
31 expander device (e.g. a cone) can be located therein.

---



1 The expander device can be provided with a seal (e.g.  
2 an O-ring or lip-type seal) so that fluid pressure is  
3 retained on one side of the device (e.g. underneath).  
4

5 The step of actuating the vibrating device typically  
6 comprises circulating fluid therethrough, although  
7 the particular method used depends upon the type of  
8 vibrating device that is used. The fluid may be  
9 circulated using any conventional means.  
10

11 The step of actuating movement of the expander device  
12 typically comprises the step of circulating fluid  
13 through the conduit and the expander device. This  
14 builds up fluid pressure (typically under the  
15 expander device), causing it to be forced upwards and  
16 thus expand the tubular member.  
17

18 The method typically includes the additional step of  
19 coupling the vibrating device into a first string.  
20 The vibrating device may be coupled into the string  
21 using any conventional means (e.g. welding, screw  
22 threads etc). The expander device is typically  
23 coupled to a second string. In certain embodiments,  
24 the first string and the second string are the same.  
25 In certain other embodiments, the first string  
26 comprises a string of drill pipe, a coiled tubing  
27 string or the like, and the second string comprises a  
28 conduit of relatively small outer diameter, e.g.  
29 drill pipe or coiled tubing. The method may also  
30 include the additional step of coupling the tubular  
31 member into the first string. The tubular member may

---

1 be coupled to the first string using any conventional  
2 means (e.g. screw threads, welding etc).

3  
4 Optionally, the method may include the additional  
5 step of circulating cement into an annulus between  
6 the tubular member and the second conduit. In this  
7 particular embodiment, the vibrating device can be  
8 used to keep the cement in the annulus moving and  
9 prevents solids within the cement from settling, both  
10 of which help to improve the final bond.

11  
12 Embodiments of the present invention shall now be  
13 described, by way of example only, and with reference  
14 to the accompanying drawings in which:

15 Fig. 1 is a schematic representation of an  
16 embodiment of apparatus for expanding a tubular  
17 member; and

18 Fig. 2 is a schematic representation of an  
19 alternative embodiment of apparatus for  
20 expanding a tubular member.

21  
22 Referring to the drawings, Fig. 1 shows a first  
23 embodiment of apparatus, generally designated 10, for  
24 use when expanding a downhole tubular 12. The  
25 downhole tubular 12 may comprise any tubular, such as  
26 drill pipe, liner, casing or the like and is  
27 typically of a ductile material so that it can be  
28 radially expanded, as will be described. The radial  
29 expansion of the tubular member 12 typically causes  
30 the member 12 to undergo plastic and/or elastic

---

1 deformation to increase its inner and outer  
2 diameters.

3

4 Plastic deformation is a result of the cone 14 being  
5 pushed through the tubular member 12, which forces  
6 the material (e.g. steel) of the member 12 to bend  
7 and stretch around the cone 14 so that it assumes a  
8 larger inner and outer diameter. This is because the  
9 wall of the tubular 12 engages the face of the cone  
10 14 and is deflected outwardly, as shown schematically  
11 in Figs 1 and 2. The material of the tubular 12 is  
12 typically ductile so that it can deform around the  
13 cone 14, providing that the cone 14 is pushed or  
14 pulled through the tubular 12 with sufficient force  
15 to stretch or bend the material of the tubular 12.  
16 The stretched configuration of the material of the  
17 tubular member 12 is typically substantially retained  
18 after the radial expansion force exerted by the cone  
19 14 is removed; the tubular member 12 relaxes slightly  
20 after is it deformed or stretched and this relaxation  
21 is termed elastic deformation. The recovery by  
22 elastic deformation is typically significantly less  
23 than the expansion by plastic deformation, and  
24 results in the inner and outer diameters of the  
25 expanded tubular member 12 reducing slightly from the  
26 initially radially expanded state.

27

28 The apparatus 10 includes an expansion cone 14 that  
29 can be of any conventional design. The expansion  
30 cone 14 is typically of a material that is harder  
31 than the material of the tubular 12 that it has to

1 expand. Steel or steel alloys can be used for the  
2 cone 12, although ceramic or tungsten carbide may  
3 also be used. It will also be appreciated that  
4 combinations of these and other materials can be  
5 used. For example, the harder materials (e.g.  
6 ceramic, tungsten carbide) can be used only on the  
7 faces of the cone 14 that come into contact with the  
8 tubular member 12 during expansion.

9  
10 The maximum outer diameter of the expander cone 14 is  
11 typically the same as or slightly less than the final  
12 inner diameter of the member 12 after it has been  
13 expanded.

14  
15 The cone 14 is typically located in a pre-expanded  
16 portion 12e of the tubular 12. However, if a  
17 collapsible cone (not shown) is used then this may  
18 not be necessary. The tubular 12 is typically  
19 located in a second conduit (not shown) in use, where  
20 the second conduit may comprise an open borehole or a  
21 pre-installed casing, liner or the like. The outer  
22 diameter of the pre-expanded portion 12e is typically  
23 less than the inner diameter of the second conduit so  
24 that the apparatus 10 can be run into the second  
25 conduit in a conventional manner.

26  
27 The expansion cone 14 can optionally include an  
28 inflatable element (e.g. a packer), the function of  
29 which shall be described below.

30

---

1 In the embodiment shown in Fig. 1, a vibrating device  
2 16 is attached using any conventional means (e.g.  
3 screw threads) to the tubular 12. The vibrating  
4 device 16 is used to impart an axial (longitudinal)  
5 and/or lateral vibration to the tubular 12 and/or  
6 cone 14. Drill pipe 18 or drill collars are  
7 typically attached above the vibrating device 16, the  
8 drill pipe 18 typically extending back to the  
9 surface. The drill pipe 18 typically forms a string  
10 of tubular drill members or the like. Coiled tubing  
11 may be used in place of the drill pipe 18. The  
12 string of drill pipe 18 or coiled tubing provides a  
13 conduit back to the surface or vessel for circulation  
14 of fluids, and also to facilitate manipulation of the  
15 tubulars and the cone 14.

16

17 The longitudinal vibration is applied on a plane that  
18 is co-planar with or parallel to a longitudinal axis  
19 of the tubular member 12 and/or the expander device  
20 14. Similarly, the lateral vibration is applied on a  
21 plane that is co-planar with or parallel to an axis  
22 that is perpendicular to the longitudinal axis of the  
23 tubular member and/or the expander device. Indeed,  
24 the vibrations may be on an axis or plane that is  
25 oblique, for example an axis that is set at an angle  
26 between the longitudinal and lateral axes.

27

28 The vibrating device 16 can be of any conventional  
29 design, and could be, for example, a Baker Oil Tools  
30 RATTLER<sup>™</sup> (product family no H14065). The RATTLER<sup>™</sup> is  
31 a downhole vibration tool that is designed primarily

1 for use in fishing operations and imparts a low  
2 frequency impact directly into a fish. The tool  
3 operates by circulating fluid therethrough and  
4 varying the amount of fluid varies the impact rate  
5 directly. A circulation sub (not shown) can be used  
6 below the tool to allow unrestricted fluid flow  
7 therethrough, and a safety joint may also be used  
8 below the tool if required.

9  
10 The tool typically imparts only a longitudinal or  
11 axial vibration, but it will be appreciated that  
12 other tools that impart longitudinal, lateral and/or  
13 oblique vibrations simultaneously or sequentially may  
14 be used.

15  
16 The frequency of vibration typically depends upon the  
17 size and type of tubular, and also the type of  
18 formation as the particular filtrate can affect the  
19 tendency of the tubular member to stick to the wall  
20 of the borehole. Thus, it may be necessary to adjust  
21 the frequency and/or amplitude of the vibrations  
22 accordingly.

23  
24 The amplitude of the vibrations can be chosen to suit  
25 the particular size and type of tubular, and also the  
26 particular filtrate that is present on the walls of  
27 the borehole.

28  
29 It will be appreciated that the frequency and/or  
30 amplitude of the vibrations provided by the vibrating  
31 device 16 can be increased and decreased during use

---

1 of the device 16. For example, where the RATTLER™ is  
2 being used, the amount of fluid that is circulated  
3 through the tool can be changed to vary the frequency  
4 of the vibration directly. That is, increasing the  
5 amount of fluid flow typically increases the  
6 frequency of vibration, and conversely, reducing the  
7 amount of fluid flow typically reduces the frequency.  
8 Also, the amount of fluid passing through the  
9 RATTLER™ can affect the amplitude of the vibrations  
10 accordingly. That is, the more fluid that is passed  
11 through the tool, the higher the amplitude of the  
12 vibrations that it imparts.

13

14 The expansion cone 14 is attached (e.g. by screw  
15 threads, welding or the like) to a length of conduit  
16 20. Conduit 20 is typically a thin pipe (e.g. with a  
17 small wall thickness and/or outer diameter) and is  
18 used as a fluid conduit between the drill pipe 18 and  
19 the expansion cone 14. The conduit 20 is located  
20 within the drill pipe 18 through a seal assembly 22  
21 that provides for upward movement of the cone 16  
22 during the expansion process whilst sealing off the  
23 interior of the tubular 12. Note that "upward" is  
24 being used with reference to the orientation of the  
25 apparatus 10 in Fig. 1.

26

27 The cone 14 is provided with a through-bore 24 and a  
28 one-way or check valve (not shown). The check valve  
29 can be incorporated as part of the conduit 20 or the  
30 drill pipe 18. This allows fluid pumped from the  
31 surface to flow down through the drill pipe 18,

1 through the conduit 20 and out through the cone 14  
2 into the tubular 12, but the check valve will not  
3 allow fluid to flow in the opposite direction. Note  
4 that tubular 12 is provided with a threaded cap 26 or  
5 other barrier (e.g. a ball catcher) that restrains  
6 fluid flow out of the tubular 12. It will also be  
7 noted that fluid flows through the vibrating device  
8 16, thus causing it to operate. It will be  
9 appreciated that some forms of vibrating device 16  
10 may not be actuated by fluid flow through them.

11  
12 Expansion is initiated by pumping fluid down the  
13 drill pipe 18 and the conduit 20. Hydraulic pressure  
14 is contained below the cone 14 at the cap 26 and this  
15 results in a build-up of pressure causing upward  
16 movement of the cone 14. The cone 14 can be provided  
17 with a seal (e.g. an O-ring or lip-type seal) that  
18 engages an inner face of the tubular 12 to retain  
19 fluid pressure below the cone 14. However, contact  
20 between an expansion face of the cone 14 and an inner  
21 face of the tubular 12 can provide a metal-to-metal  
22 seal.

23  
24 Movement of the cone 14 causes it to engage the  
25 tubular 12 and thus radially expand the tubular 12 by  
26 plastically and/or elastically deforming it. The  
27 expansion of the tubular 12 can be used to cause it  
28 to engage the second conduit in which it is located,  
29 although this is not essential as a spacer, seal,  
30 packer or the like can be used therebetween. Also,

---



1 cement can be used in the annulus between the tubular  
2 12 and the second conduit, as will be described.

3  
4 The inflatable element that can be included as part  
5 of the cone 14 can be used to further inflate the  
6 pre-expanded portion 12e into contact with the second  
7 conduit. Also, the inflatable element can be used as  
8 a temporary anchor that secures the tubular 12 and  
9 holds it in position whilst it is being radially  
10 expanded. The inflatable element can either be  
11 deflated so that it moves with the cone 14, or can be  
12 released therefrom so that the cone 14 travels on its  
13 own, the inflatable element being recovered  
14 thereafter. A conventional latching mechanism can be  
15 used to couple the inflatable element to the cone 14,  
16 if required.

17  
18 The fluid flow also activates the vibrating device 16  
19 and the vibration therefrom keeps the tubular 12  
20 moving and substantially prevents it from becoming  
21 differentially stuck. It will be appreciated that  
22 the tubular 12 may become differentially stuck if it  
23 is not centralised within the second conduit  
24 (typically a borehole).

25  
26 Note that the tubular 12 can be vibrated whilst it is  
27 being run into the second conduit by circulating  
28 fluid as described above. It will be appreciated  
29 that a ball catcher (not shown) may be used in place  
30 of the threaded cap 26 to allow fluid to be  
31 circulated whilst the apparatus 10 is being run in.

---

1 This is particularly advantageous where the tubular  
2 12 is being located in a long, deviated or horizontal  
3 borehole where it is likely that the tubular 12 will  
4 become differentially stuck.

5  
6 It will also be appreciated that cement can be  
7 circulated (using any conventional means) in the  
8 annulus between the tubular 12 and the second conduit  
9 to keep the tubular 12 in place. The threaded cap 26  
10 can be drilled out to allow for the circulation of  
11 cement in the conventional manner. The vibrations  
12 from the vibrating device 16 will help to keep the  
13 cement moving between the second conduit and the  
14 tubular 12, and can also help prevent solids in the  
15 cement from settling, thus improving the final bond  
16 between the tubular 12 and the second conduit.

17  
18 A further advantage of the apparatus 10 is that the  
19 expansion process does not require any movement of  
20 the drill pipe 18. Movement of the expansion cone 14  
21 is decoupled from movement of the drill pipe 18 and  
22 thus the tubular 12. Additionally, in the event that  
23 the expansion cone 14 becomes stuck, the drill pipe  
24 18 and vibrating device 16 can be removed from the  
25 second conduit and remedial action can be taken to  
26 retrieve the conduit 20 and expansion cone 14.

27  
28 It will be appreciated that once the tubular 12 has  
29 been radially expanded, the drill pipe 18 can be  
30 rotated against the tubular 12 to release the pipe 18  
31 from the tubular 12 so that the tubular 12 remains in

---

1     *situ*. The remainder of the apparatus can then be  
2     withdrawn from the borehole.

3  
4     Alternatively, the tubular 12 can be provided with a  
5     screw-threaded attachment at an end thereof so that  
6     when the tubular 12 is radially expanded, the screw-  
7     threads are released from the threads on the  
8     vibrating device 16, allowing the apparatus to be  
9     retrieved whilst the tubular 12 remains *in situ*.

10  
11    Referring now to Fig. 2, there is shown an  
12    alternative apparatus 100 for expanding a tubular  
13    112. Apparatus 100 is similar to apparatus 10 and  
14    like parts shall be designated with the same  
15    reference numeral pre-fixed "1".

16  
17    The main difference between apparatus 100 and  
18    apparatus 10 is that the vibrating device 116 is  
19    located in the conduit 120 and the tubular 112 is  
20    coupled directly to the drill pipe 118. The  
21    vibrating device 116 can be used to impart lateral  
22    and/or radial vibrations to the cone 114, which can  
23    be transferred to the tubular 112 either by contact  
24    between the cone 114 and the tubular 112, or through  
25    the seal assembly 122. This embodiment thus has the  
26    same advantages and benefits as the previous  
27    embodiment.

28  
29    In addition to those, the vibrating device 116 can be  
30    used to impart longitudinal and/or lateral vibrations  
31    to the cone 114. The vibrations reduce the friction

---

1     between the cone 114 and the tubular 112, thus making  
2     the expansion process more efficient.

3

4     Modifications and improvements may be made to the  
5     foregoing without departing from the scope of the  
6     present invention.

---

1     CLAIMS

2

3     1.   Apparatus for expanding a tubular member, the  
4     apparatus comprising a vibrating device (16, 116)  
5     and an expander device (14, 114).

6

7     2.   Apparatus according to claim 1, wherein the  
8     vibrating device (16, 116) is capable of imparting a  
9     longitudinal and/or lateral and/or oblique vibration  
10    to the expander device (14, 114) and/or the tubular  
11    member (12, 112).

12

13    3.   Apparatus according to either preceding claim,  
14    wherein the vibrating device (16, 116) is actuated  
15    by a flow of fluid therethrough.

16

17    4.   Apparatus according to claim 1 or claim 2,  
18    wherein the vibrating device (16, 116) is  
19    electrically-operated or petrol- or diesel-driven.

20

21    5.   Apparatus according to any preceding claim,  
22    wherein the expander device (14, 114) comprises an  
23    expansion cone.

24

25    6.   Apparatus according to any preceding claim,  
26    wherein the expander device (14, 114) is attached to  
27    a conduit (20, 120).

28

29    7.   Apparatus according to claim 6, wherein the  
30    conduit (20, 120) has a relatively small diameter.

31

- 1     8.   Apparatus according to claim 6 or claim 7,  
2     wherein the vibrating device (16, 116) is coupled to  
3     the tubular member (12, 112) that is to be expanded.  
4
  - 5     9.   Apparatus according to claim 8, wherein the  
6     tubular member (12) and the vibrating device (16)  
7     are coupled into a string (18).  
8
  - 9     10.  Apparatus according to claim 9, wherein a seal  
10    assembly (22) is located between the conduit (20)  
11    and the tubular member (12).  
12
  - 13   11.  Apparatus according to claim 10, wherein the  
14    seal assembly (22) allows the conduit (20) with the  
15    expander device (14) to move, whilst the tubular  
16    member (12) and string (18) remain stationary.  
17
  - 18   12.  Apparatus according to claim 6, wherein the  
19    vibrating device (116) is coupled into the same  
20    conduit (120) as the expander device (114).  
21
  - 22   13.  Apparatus according to claim 12, wherein the  
23    tubular member (112) is coupled into a string (118).  
24
  - 25   14.  Apparatus according to claim 13, wherein a seal  
26    assembly (122) is located between the conduit (120)  
27    and the string (118).  
28
  - 29   15.  Apparatus according to claim 14, wherein the  
30    seal assembly (122) allows the conduit (120) with  
31    the expander device (114) to move, whilst the
-

1 tubular member (112) and string (118) remain  
2 stationary.  
3

4 16. Apparatus according to any preceding claim,  
5 wherein the expander device (14, 114) is provided  
6 with a through-bore (24, 124) or aperture that  
7 allows fluid to pass through the conduit (20, 120)  
8 to which it is attached, and also through the  
9 expander device (14, 114).  
10

11 17. Apparatus according to any preceding claim,  
12 wherein an end of the tubular member (12, 122) is  
13 closed.  
14

15 18. A method of expanding a tubular member in a  
16 borehole, the method comprising the step of  
17 vibrating the tubular member (12, 112) before,  
18 during and/or after expansion.  
19

20 19. A method according to claim 18, wherein the  
21 step of vibrating the tubular member (12, 112)  
22 includes the additional step of actuating a  
23 vibrating device (16, 116) attached to the tubular  
24 member (12, 112).  
25

26 20. A method according to claim 19, wherein the  
27 step of actuating the vibrating device (16, 116)  
28 comprises circulating fluid therethrough.  
29

30 21. A method according to any one of claims 18 to  
31 20, wherein the method includes the step of  
32 actuating movement of an expander device (14, 114)

1 to impart a radial expansion force to the tubular  
2 member (12, 112).

3

4 22. A method according to any one of claims 18 to  
5 21, wherein the method includes the additional step  
6 of coupling the vibrating device (16, 116) into a  
7 first string (18).

8

9 23. A method according to claim 22, wherein the  
10 method includes the additional step of coupling the  
11 expander device (14, 114) into a second string (20,  
12 120).

13

14 24. A method according to any one of claims 18 to  
15 23, wherein the tubular member (12, 112) is vibrated  
16 on a longitudinal and/or lateral and/or oblique  
17 axis.

18

19 25. A method of expanding a tubular member in a  
20 borehole, the method comprising the step of  
21 vibrating an expander device (14, 114) during  
22 expansion of the tubular member (12, 112).

23

24 26. A method according to claim 25, wherein the  
25 step of vibrating the expander device (14, 114)  
26 includes the additional step of actuating a  
27 vibrating device (16, 116) attached to the expander  
28 device (14, 114).

29

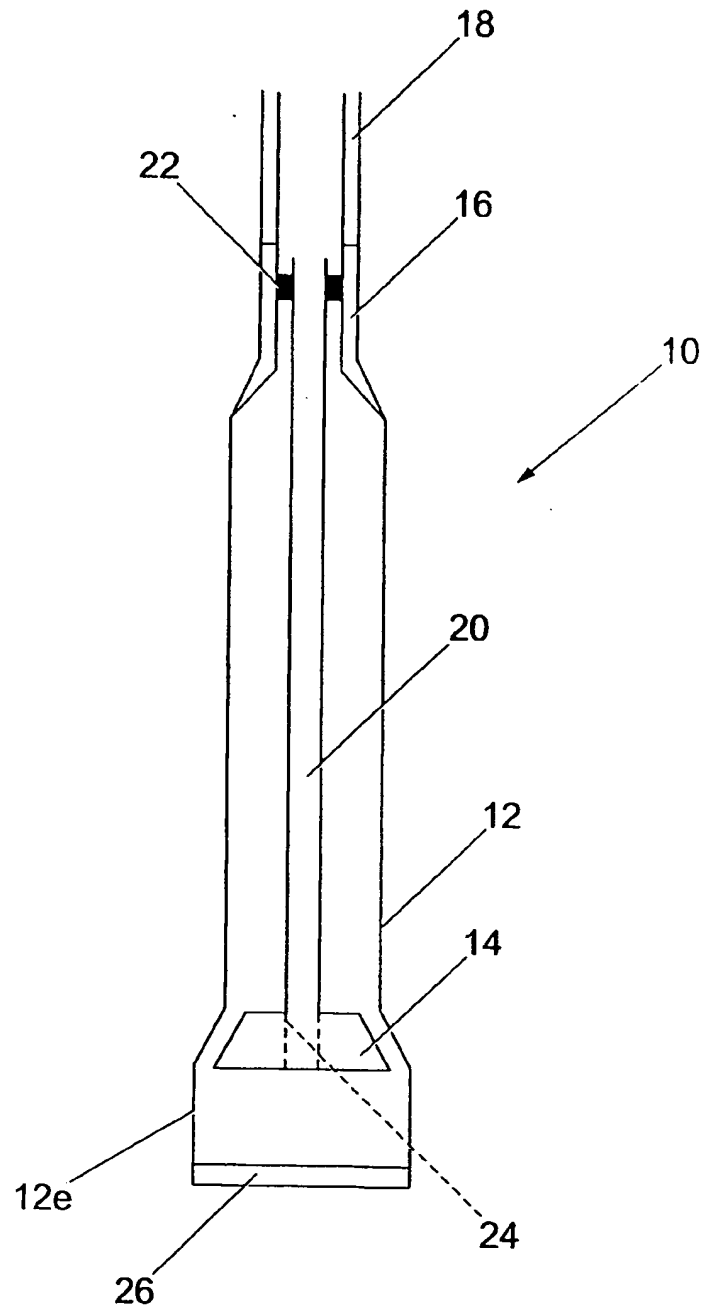
30 27. A method according to claim 26, wherein the  
31 step of actuating the vibrating device (16, 116)  
32 comprises circulating fluid therethrough.



- 1  
2 28. A method according to any one of claims 25 to  
3 27, wherein the method includes the step of  
4 actuating movement of an expander device (14, 114)  
5 to impart a radial expansion force to the tubular  
6 member (12, 112).  
7
- 8 29. A method according to any one of claims 18 to  
9 23, wherein the expander device (14, 114) is  
10 vibrated on a longitudinal and/or lateral and/or  
11 oblique axis.  
12
- 13 30. A method of preventing a string from becoming  
14 stuck in a wellbore, the method comprising the steps  
15 of vibrating the string (18) while being run into  
16 the wellbore.  
17
- 18 31. A method according to claim 30, wherein the  
19 step of vibrating the string (18) comprises the step  
20 of actuating a vibrating device (16).  
21
- 22 32. A method according to claim 31, wherein the  
23 step of actuating the vibrating device (16)  
24 comprises circulating fluid therethrough.  
25
- 26 33. A method according to any one of claims 30 to  
27 32, wherein the method includes the additional step  
28 of coupling the vibrating device (16) into the  
29 string (18).  
30
-

- 1 34. A method according to any one of claims 30 to
  - 2 33, wherein the string (18) is vibrated on a
  - 3 longitudinal and/or lateral and/or oblique axis.
-

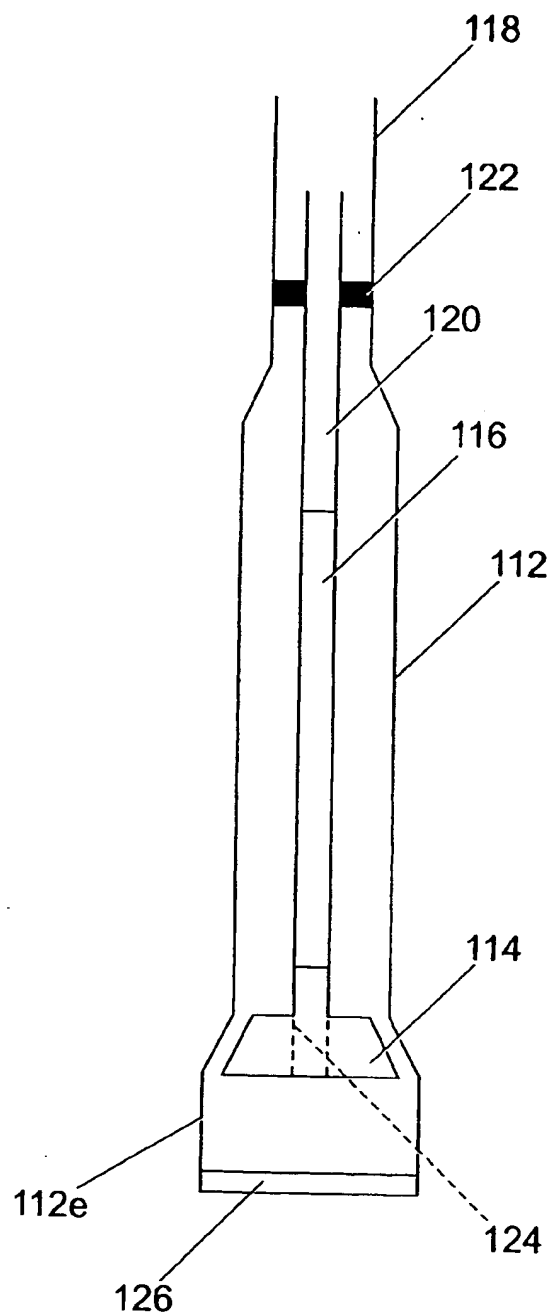
1 / 2



*Fig. 1*

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2 / 2

*Fig. 2*

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## INTERNATIONAL SEARCH REPORT

Intern al Application No

PCT/GB 03/00138

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 E21B43/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages                                     | Relevant to claim No. |
|------------|--|-----------------------|
| A          | WO 98 00626 A (SHELL CANADA LTD ;SHELL INT RESEARCH (NL)) 8 January 1998 (1998-01-08)<br>page 7, line 9-12<br>figure 1 | 1, 18, 25,<br>30      |
| X          | US 4 058 163 A (YANDELL JAMES L)<br>15 November 1977 (1977-11-15)<br>abstract  | 30-34                 |
| X          | US 4 384 625 A (ROPER WILBUR F ET AL)<br>24 May 1983 (1983-05-24)<br>column 6, line 50-54<br>figure 1                  | 30-34                 |
| X          | GB 2 261 238 A (BP EXPLORATION OPERATING)<br>12 May 1993 (1993-05-12)<br>page 4, line 31 -page 5, line 5               | 30-34                 |
|            | -/--   |                       |



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents:

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Date of the actual completion of the International search

21 May 2003

Date of mailing of the International search report

27/05/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5618 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel (+31-70) 340-2040, Tx 31 651 epo nl,  
Fax (+31-70) 340-3016

Authorized officer

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## INTERNATIONAL SEARCH REPORT

Intern al Application No

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No. |
|------------|--|-----------------------|
| X          | GB 2 272 924 A (BP CHEM INT LTD ;BP<br>EXPLORATION OPERATING (GB))<br>1 June 1994 (1994-06-01)<br>page 3, line 5-14<br>claim 1 | 30-34                 |
| X          | US 4 890 682 A (WORRALL ROBERT N ET AL)<br>2 January 1990 (1990-01-02)<br>abstract<br>claim 19<br>figure 1                     | 30-34                 |

# INTERNATIONAL SEARCH REPORT

I ational application No.  
PCT/GB 03/00138

## Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
  
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this International application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
  
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
  
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/GB 03 00138

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-29

Method and apparatus for expanding a tubular member comprising a vibrating device and an expander.

2. Claims: 30-34

A method of preventing a string from becoming stuck in a wellbore by vibrating the string while running in.



## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 03/00138

| Patent document<br>cited in search report |   | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|---|---|---------------------|----------------------------|---------------------|
| WO 9800626                                | A | 08-01-1998          | AU 723337 B2               | 24-08-2000          |
|   |   |                     | AU 3442097 A               | 21-01-1998          |
|   |   |                     | BR 9710016 A               | 10-08-1999          |
|   |   |                     | CA 2260191 A1              | 08-01-1998          |
|   |   |                     | EA 543 B1                  | 28-10-1999          |
|   |   |                     | WO 9800626 A1              | 08-01-1998          |
|   |   |                     | EP 0907822 A1              | 14-04-1999          |
|   |   |                     | JP 2001508144 T            | 19-06-2001          |
|   |   |                     | NO 986171 A                | 22-02-1999          |
|   |   |                     | NZ 333945 A                | 27-03-2000          |
| US 4058163                                | A | 15-11-1977          | NONE                       |                     |
| US 4384625                                | A | 24-05-1983          | CA 1167832 A1              | 22-05-1984          |
|   |   |                     | GB 2088438 A ,B            | 09-06-1982          |
|   |   |                     | NO 814043 A                | 01-06-1982          |
| GB 2261238                                | A | 12-05-1993          | NONE                       |                     |
| GB 2272924                                | A | 01-06-1994          | NONE                       |                     |
| US 4890682                                | A | 02-01-1990          | CA 1319675 A1              | 29-06-1993          |
|   |   |                     | DE 3776959 D1              | 09-04-1992          |
|   |   |                     | EP 0245892 A2              | 19-11-1987          |

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